RT&A, Special Issue No 5 (75)
Volume 18, November 2023

THE KURA ACTIVE FAULT – POTENTIAL SOURCE OF SIGNIFICANT HAZARD

Alexander Strom

•

JSC "Hydroproject Institute", Russia
strom.alexandr@yandex.ru

Abstract

An active fault stretching for more than 100 km along the Kura River between the tailing part of the Mingeçevir Reservoir in the east and the Azerbaijan-Georgia border in the west – the so-called Kura fault – is described in brief based on the analysis of space images. This active reverse fault with distinct evidence of Late Quaternary movements crosses the waterfronts of the Shamkir and the Enikend reservoirs. Considering its expressiveness and location just at the foundations of the hydraulic structures it seems that hazard posed by this active fault could be underestimated and that more efforts should be undertaken to reveal its recent history.

Keywords: Kura fault, surface rupture, earthquake magnitude, single-event displacement

I. Introduction

Active faults pose a significant threat to communities and infrastructure. They produced dual hazard, being considered as main causative tectonic structures responsible for large earthquakes, and, besides that, being able to destroy or damage any artificial structure if surface rupture would occur directly at structure foundation. Such phenomenon occurred, for example, during the 1999 Chi-Chi earthquake in Taiwan when concrete dam was ruptured by a fault stretching along the river [1, 2].

An active fault more than 100 km long stretches along the Kura River in the Western Azerbaijan between the tailing part of the Mingeçevir Reservoir in the east and the Azerbaijan-Georgia border in the west (Fig. 1), crossing waterfronts of the Şəmkir and the Yenikend reservoirs (Fig. 2). This fault named the Kura fault, has been known as an active tectonic structure since 90th, when it was identified by M.L. Kopp (unpublished data). It is included in the Eurasia Database of Active Faults (EDAF) [3, 4] with confidence level "C" that means that "*few pieces of evidence of activity are known as well as the lack of seismicity, the lack of surface deformations, or both*" [4].

Indeed, no one large earthquake has been reported here in the historical times. However, statement of "*the lack of surface deformations*" along this tectonic structure is wrong, as it will be demonstrated hereafter based on the analysis of the remote sensing data. These findings specified the exact location of the Kura active fault at some sections and demonstrate that hazard posed by this fault seems to be underestimated significantly, both for the hydraulic schemes directly crossed by it, and for the entire region that might be affected if large earthquakes could originate along the Kura fault considered as a causative structure capable for such events.

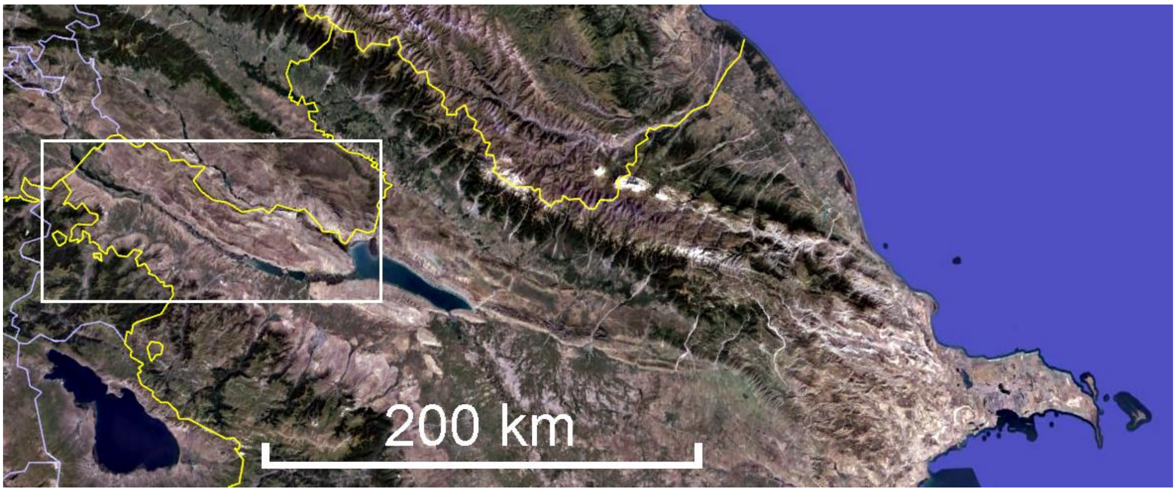

Fig. 1: *Position of the study area in Northern Azerbaijan (marked by white rectangle)*

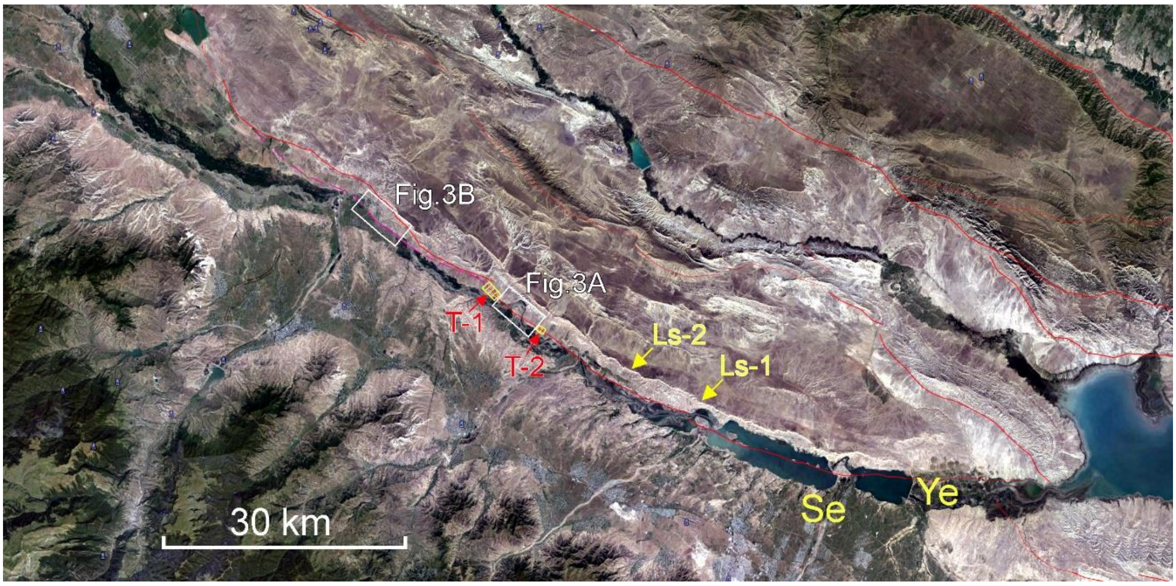

Fig. 2: *Space image of the area marked in Fig. 1. Red lines – active faults according to the EDAF. Pink lines specified position of the Kura active faults. Ye – the Yenikend HPP, S - the Şəmkir HPP, white rectangles – fault sections shown in Fig. 3A and B; T-1 and T-2 – sites most suitable for trenching shown in Figs 4 and 5; arrows marked by Ls-1 and Ls-2 indicate sites with deep seated graviratіonal slope deformations shown in Figs. 6 and 7*

II. Geomorphic evidence of recent faulting

Distinct evidence of recent activity can be found along the entire length of the Kura faut. The most impressive are remnants of the uplifted north-eastern side visible on the right bank of the river where they are cut by the meandering stream (Fig. 3). Steep south-western slopes of these remnants, 15 to 40 m high, coincide with the reverse fault along which the hanging wall was thrusted over the flat plains of the footwall. Such cumulative displacement accumulated during last stage of the Kura fault long-tern evolution. The fact that the Kura River meanders have been incised locally through uplifting hanging wall indicates that there should be some period of the stabilization when meandering stream had crossed the fault line migrating from the footwall to hanging wall and back. When fault movements had activated, the stream could not leave its circuitous course and, due to intensive bottom erosion separated these remnants from the main ridge bounded by the Kura River valley at the south-east and the Yori River valley in the northwest that forms the uplifted hanging wall of the Kura reverse fault.

At some sections the frontal edge of the hanging wall is even slightly higher that its part passing closer to the main ridge that might be caused by some flattening of the deeper part of the fault plane. Such structural peculiarities were described in several mountain systems characterized by intensive transverse shortening and reverse or thrust faulting, in Central Tien Shan near the Naryn town in particular [5].

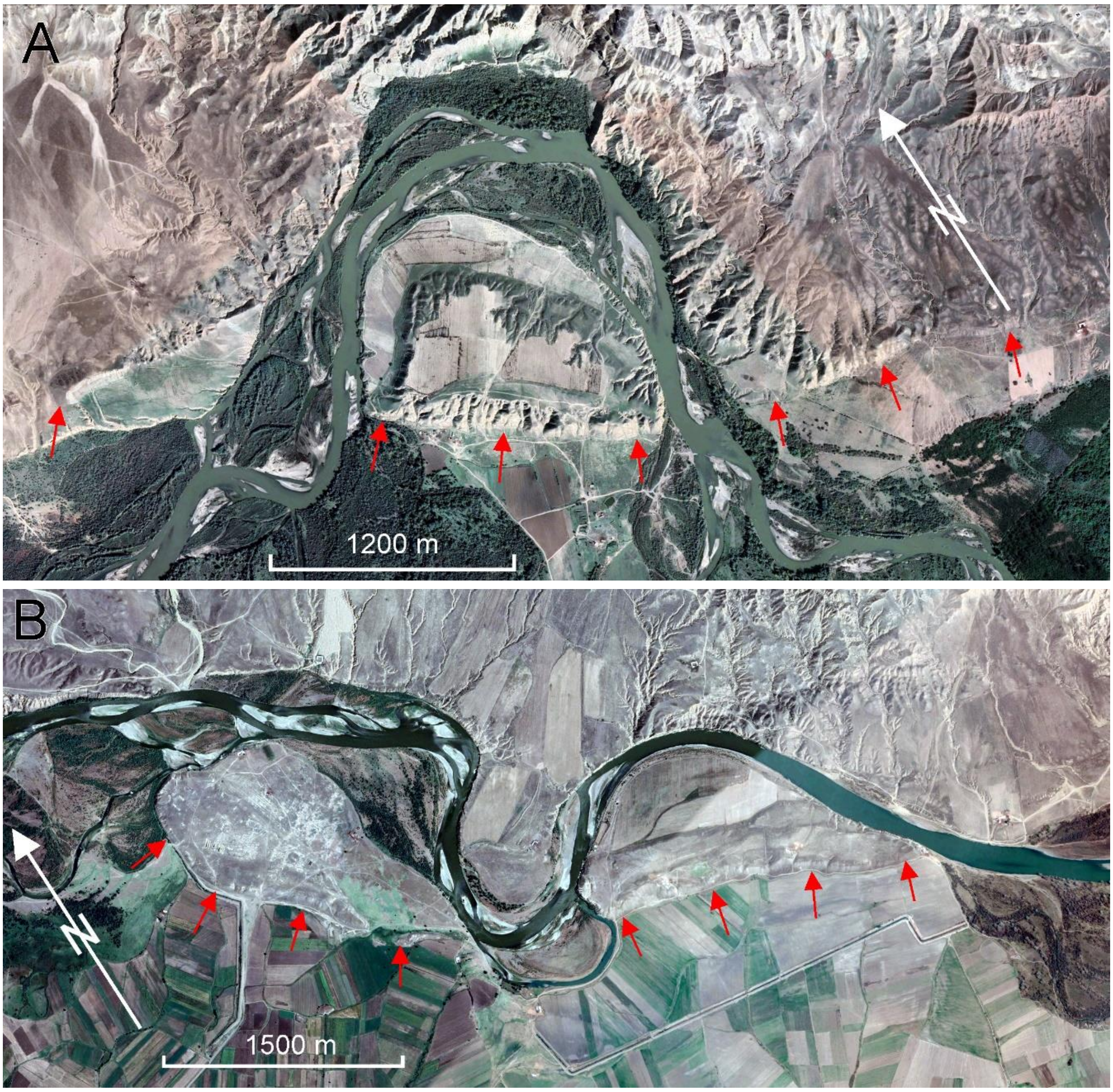

Fig. 3: *Remnants of the Kura fault hanging wall on the right bank of the River, separated from the main uplifted block by the meandering stream. A - 8 km upstream from the Kirzan village; B – 2 km east from the Qiraq Kesamen village*

III. Sites suitable for detail investigations

Despite impressiveness of landforms shown in Fig. 3 and reflecting recent activity of the Kura fault, detail paleoseismological studies should be carried out to restore most recent history of its evolution. They will require extensive trenching that is the main technique to derive information critically important for seismic hazard assessment: 1) mode of fault displacement – was it the permanent tectonic creep or periodic rupturing events associated with earthquakes and what is the long-tern sleep rate of the Kura fault; 2) ages of the recurrent rupturing events and, therefore, their recurrence interval; 3) amount of single-event offsets that allows estimating magnitudes of past earthquakes [6]. One more aim of trenching is to select fault section(s) affected by single-event rupturing episodes. Such information is also very important to derive magnitudes of such seismotectonic events since rupture length is correlated with earthquake magnitude [7 - 9]. Such study, however, requires extensive trenching at numerous sides distributed along the entire fault length. It should be also noticed that, since no significant permanent deformations of the Şəmkir and the Yenikend HPP waterfronts have been reported yet, most likely the Kura fault evolves in the periodic rupturing events mode with minimal or zero deformations between these episodes.

Planning such studies, one should consider that trenching at the sites with significant – up to 40 m cumulative vertical offset where active fault crosses the river meanders will be too laborious. Besides, in the footwall, where the colluvial wedges could be accumulated and, thus, where trenching should be most informative, trenching could face difficulties caused by groundwater inflow, that will require trench draining that would be quite problematic.

The most appropriate sites for trenching are those where fault scarp height does not exceed several meters, located at some distance from the river floodplain and above its level where watertable should be at the significant depth. Two fault sections with such conditions were selected on space images. One is located at 41.142° N, 45.662° E (Fig. 4); another one – about 8.5 km from the first one, at 41.096° N, 45.74° E. (Fig. 5).

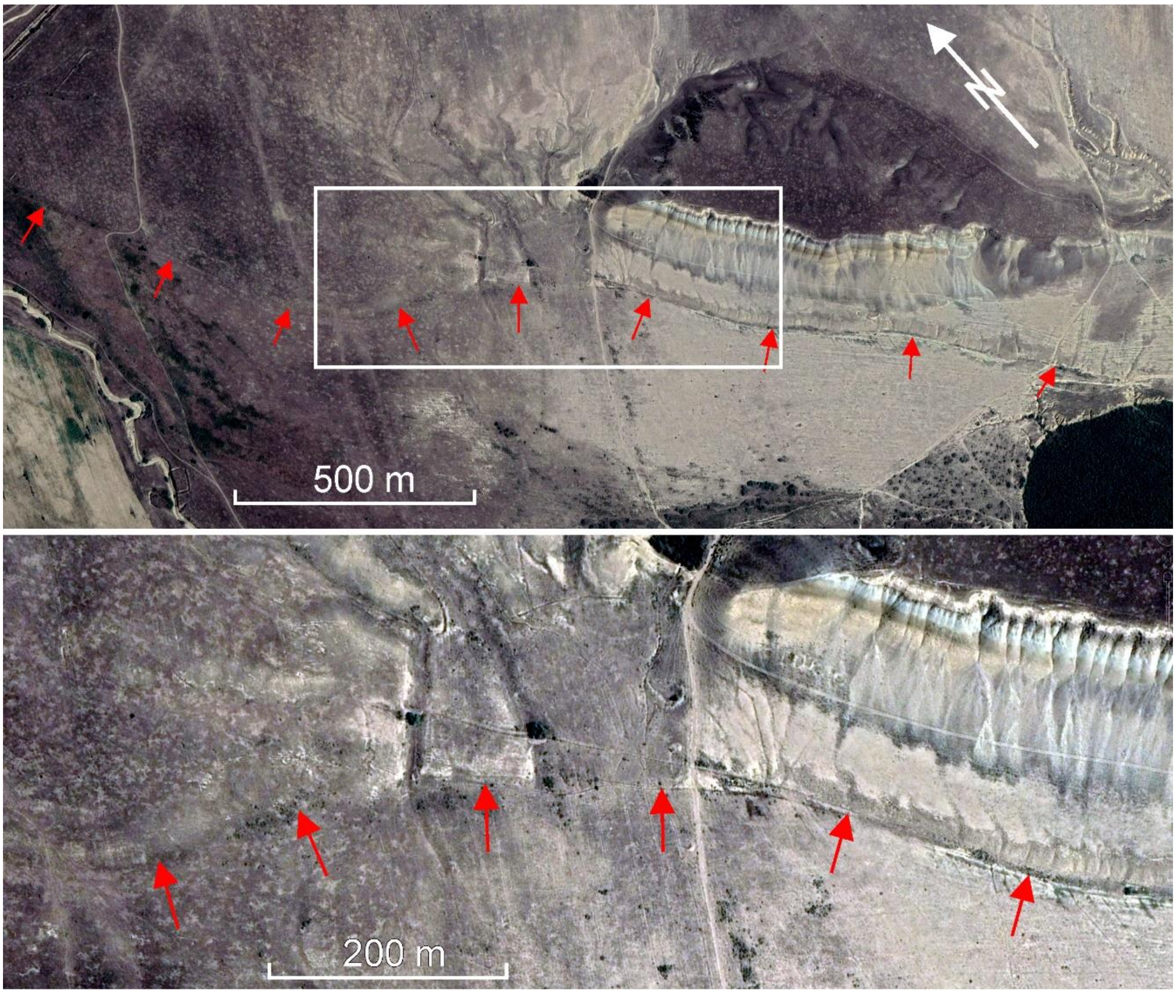

Fig. 4: *The Kura fault sections at 41.14° N, 45.66° E with 3-5 m high fault scarp marked by red arrows, optimal for trenching (T-1 in Fig. 2). The lower image is the zoomed fragment outlined above.*

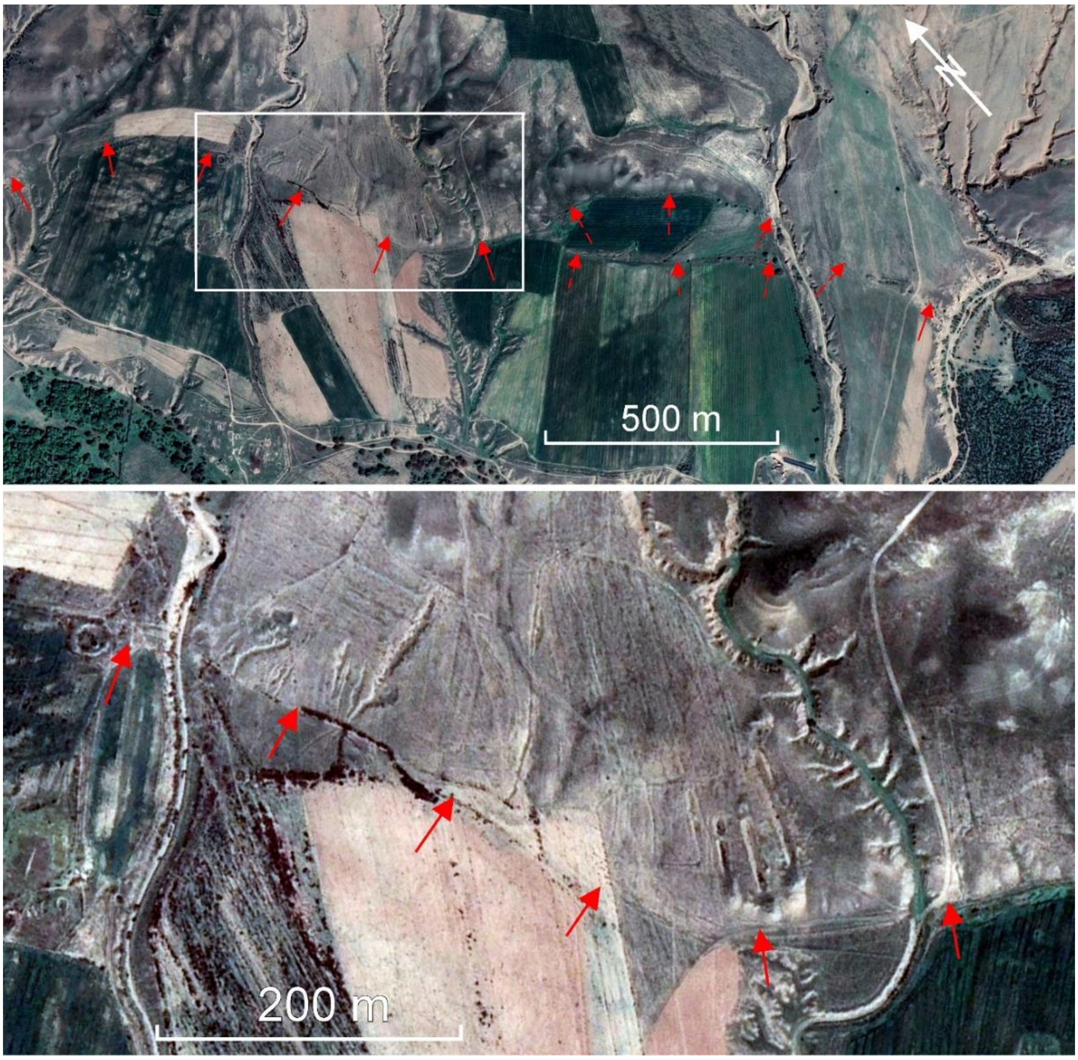

Fig. 5: *The Kura fault sections at 41.097° N, 45.74° E with 4-5 m high scarp marked by red arrows, optimal for trenching (T-2 in Fig. 2) . The lower image is the zoomed fragment outlined above. The indubitable fault scarp is marked by solid arrows, the assumed section – by dashed arrows*

At both sites hanging wall of the up to 5 m high fault scarp is incised by several young dry gullies that almost disappear at the footwall, indicating recent activity of the Kura fault. Trenching at these sites should provide information on the most recent rupturing events. According to the space images available, local areas at both sites are not used for cropping, thus such earthwork will not disturb local farmers. Of course, more sites should be selected for trenching to trace single-event ruptures, but those described above looks most promising to start trenching campaign.

IV. Slope deformations of the hanging wall

Besides distinct evidence of recent faulting described in brief above, evidence of large-scale slope deformations can be seen at several sections along the crest of the ridge that forms the hanging wall of the Kura fault. The most evident deformations (Fig. 6) are at 41.02° N, 45.98° E. One more, less impressive site where, nevertheless, fractures on top of the ridge stretch for about 1200 m passing up to 300 m behind the watershed was found at 41.057° N, 45.87° E (Fig. 7). It should be pointed out that fractures at the latter site are well visible on space images made in April 2014 and available at Google Earth. Later the top of the ridge underwent intensive agricultural development that masked these fractures.

Such fractures bounding large blocks and extending far behind the watershed, thus, affecting the ridge crest and upper part of the opposite slope, indicate formation of the deep-seated gravitational slope deformations (DSGSD) [10, 11]. DSGSDs are typical of hanging walls of active reverse faults and can be triggered by earthquakes associated with such faults.

Fig. 6: *Deep seated gravitational slope deformation on top of the ridge above the tail part of the Şəmkir reservoir (Ls-1 in Fig. 2). Scarps are marked by orange arrows*

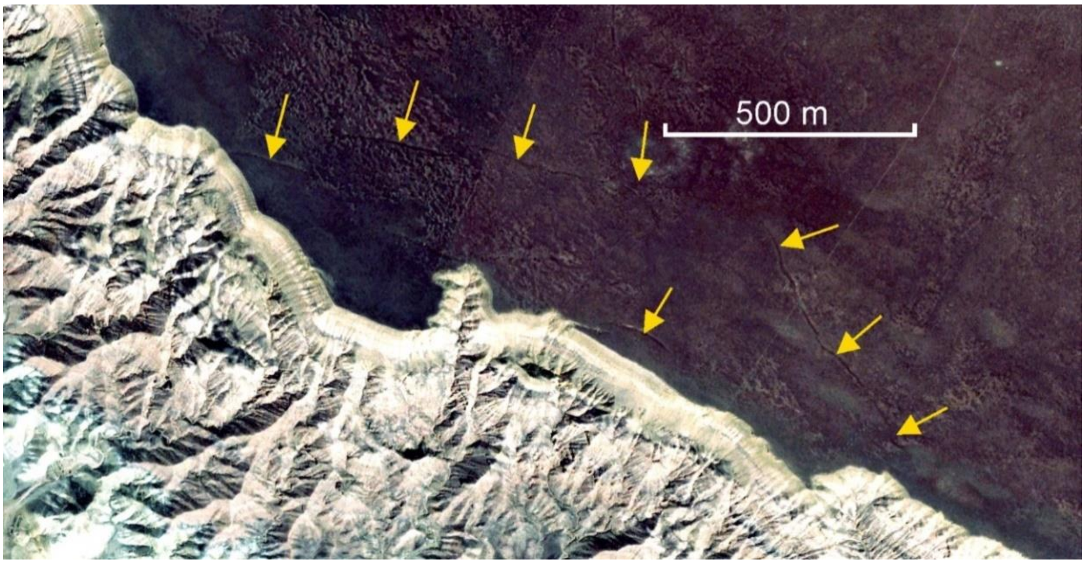

Fig. 7: *Fissured indicating the initial stage of the deep seated gravitational slope deformation on top of the ridge (Ls-2 in Fig. 2). Fractures are marked by orange arrows. Image made on April 5, 2014*

V. Discussion and conclusions

The aim of this paper is to attract attention of researchers studying active tectonics and seismic hazard of Transcaucasian region to this, potentially quite hazardous active fault. According to the data presented herein, the confidence level of the Kura fault should be changed to "CONF B" (*denotes unambiguous surface deformations, although no recent slips have been described yet, and the* *attribution of earthquakes is questionable* [4]). Results of more detailed studies could even change it to "CONF A", if structural and sedimentological evidence of past earthquakes will be identified by trenching [6]. Much higher confidence level should be considered for assessing hazard that this active fault poses to Western Azerbaijan and neighboring parts of Georgia and Armenia, and, in particular, to hydraulic schemes along the Kura River that might be affected by surface faulting associated with this tectonic structure directly.

If periodic rupturing mode of the Kura fault evolution will be proved, magnitude of the past and, correspondingly, of possible future earthquakes could be derived based on the empirical relationships between single-event displacement and surface rupture length on the one hand and earthquake magnitude, either M_w [7, 8] or Ms [9], on the other hand. Considering significant overall length of the Kura fault and assumed multimeter single-event offsets, magnitude of earthquakes that might be associated with this fault could be quite high. Depending on the ages of past events and on the duration of their return period assumed seismic effects could exceed those provided by the previous estimates and considered in construction codes [12].

References

[1] Lee, J. C., Chu H.-T., Angelier J., et al. (2002). Geometry and structure of northern surface ruptures of the 1999 Mw = 7.6 Chi-Chi Taiwan earthquake: Influence from inherited fold belt structures. *Journal of Structural Geology* 24, 173–192.

[2] Lin A., Oichi T., Chen A. and Maruyama T. (2001). Co-seismic displacements, folding and shortening structures along the Chelungpu surface rupture zone occurred during the 1999 Chi-Chi (Taiwan) earthquake. *Tectonophysics* 330, 225–244.

[3] Bachmanov, D. M., Trifonov V. G., Kozhurin, A.I.. Zelenin, E. A. (2022). Active Faults of Eurasia Database AFEAD version 2022. DOI: 10.13140/RG.2.2.25509.58084

[4] Zelenin E. A, Bachmanov D. M., Garipova S. T., Trifonov V. G., Kozhurin A .I. (2022). The Active Faults of Eurasia Database (AFEAD): the ontology and design behind the continental-scale dataset. *Earth System Science Data*.. vol. 14. p. 4489-4503.

[5] Abdrakhmatov, K.E., Thompson, S., Weldon, R.. Active tectonics of the Tien Shan. Bishkek, Ilim Publishers, 2007. (in Russian).

[6] McCalpin, J.P. Paleoseismology, 2nd Edition. International Geophysics Series, Vol. 95. Elsevier, 2009.

[7] Wells, D.L., and Coppersmith, K.J. (1994). New empirical relationships among magnitude, rupture length, rupture width, rupture area, and surface displacement. *Bulletin of the Seismological Society of America.* 1994. V. 4. 974–1002.

[8] Leonard, M. (2010). Earthquake fault scaling: self-consistent relating of rupture length,width, average displacement, and moment release. *Bulletin of the Seismological Society of America,* V. 100, No. 5A, 1971–1988,

[9] Strom, A.L. and Nikonov, A.A. (1997). Relationships between seismic faults parameters and earthquakes' magnitude. *Izvestia, Physics of the Earth.* 33(12): 1011-1022.

[10] Jomard, H., Lebourg, Th., and Guglielmi, Y. (2014). Morphological analysis of deep-seated gravitational slope deformation (DSGSD) in the western part of the Argentera massif. A morpho-tectonic control? *Landslides*, 11, 107-117.

[11] Pánek, T., and Klimeš, J. (2016). Temporal behavior of deep-seated gravitational slope deformations: A review, *Earth Science Reviews*. 156, 14-38.

[12] Akhundov, A., Mammadli, T., Garaveliyev, E., Yethirmishli, Q., and Tanircan G. (2010) Seismic hazard assessment for Azerbaijan. The NATO Science for Peace and Security Programme.